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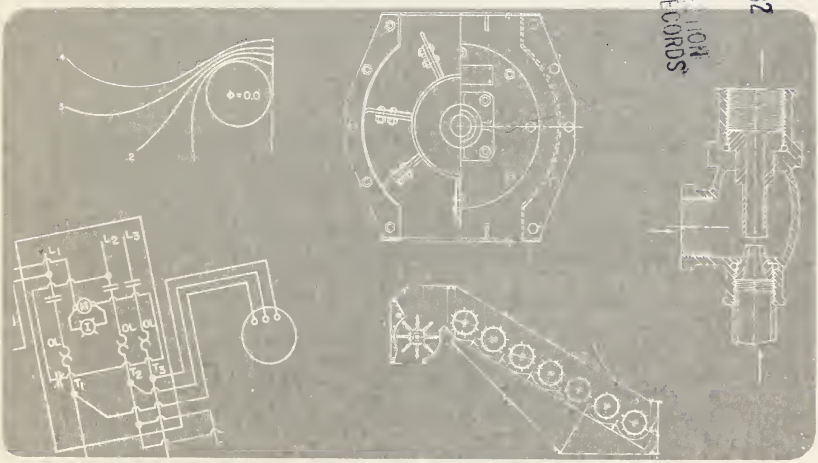
Energy Conservation in Lighting Livestock-Slaughter Plants



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"Utility Usage in Small Slaughter Plants," by Clayton F. Brasington. U.S. Agricultural Research Service Report ARS-S-174, 17 pp., illus. (1978).

"Layout Guide for Small Meat Plants," by Clayton F. Brasington and Donald R. Hammons. U.S. Department of Agriculture Marketing Research Report 1057, 27 pp., illus. (1976).

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CONTENTS

ILLUSTRATIONS

TABLES

Energy Conservation in Lighting Livestock-Slaughter Plants

By Clayton F. Brasington[1]

ABSTRACT

The lighting at six small, regional, livestock-slaughter plants in Oklahoma and Texas was studied as part of a larger study designed to help develop energy-conservation guidelines for such plants. The present lighting at the plants is evaluated, the most energy-efficient lamps for work and storage areas are recommended, and the energy and dollar savings made possible by installing the recommended lamps and adopting energy-conservation procedures is calculated. The data from this study can also be used to appraise light sources at other meat industry plants regardless of their volume or type of operation. Index terms: energy conservation, energy consumption, illumination, lighting, livestock-slaughter plants, meatpacking plants, meat-processing plants, slaughterhouses.

INTRODUCTION

Because the meatpacking industry had been identified as one of the 10 most energy-intensive industries in the United States, the American Meat Institute created a task force in 1974 to develop an energy conservation plan for the meat industry. In 1975 this task force recommended that by 1980 plants should voluntarily reduce their energy use by 10 percent of what they used in 1972. A recent report from 37 of the larger meatpackers that represent about 50 percent of this country's meat production shows that for the last half of 1978 they reduced energy consumption by 27 percent compared to 1972, but many smaller plants have not reduced their energy usage significantly. These plants (designated regional plants since they supply a significant portion of the meat and meat products consumed in their region) slaughter fewer than 300 cattle and hogs daily; receive most of their animals from nearby farms, ranches, auctions, and feedlots; and normally ship carcasses, fabricated meats, and processed products to public feeders, retail outlets, and other processing plants in their area.

Regional plants usually have one or more workers to service and perform minor repairs on equipment and facilities and may have an engineer to plan and supervise the maintenance work, but in most cases, the maintenance staff does not have the time or expertise to conduct energy audits. Plant operators occasionally attend or send personnel to energy conservation workshops, but it is doubtful if such limited training can be used to develop a comprehensive energy conservation program. Plants that do not have or use qualified employees to plan and conduct effective energy conservation programs are called low-technology plants.

To better understand the energy conservation problems faced by low-technology meatpackers, 37 plants were visited in Arkansas, Louisiana, Oklahoma, and Texas. Background information was obtained on plant operations and volume, changes made within the last few years to increase

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operating efficiency, and management's plans for coping with possible future energy shortages and rising energy costs. Six regional slaughter plants were selected for detailed engineering studies on how energy was used at each facility. Four of the plants had slaughter floors for dressing cattle, and two had floors for dressing cattle and hogs. The plants were from 10 to 30 years old, and all the plants had been remodeled and expanded at least once.

Operators provided information on the slaughter volume, carcass weights, and energy consumed each month for 12 months. We also collected information on the type and size of work and storage areas and on the equipment provided for performing various slaughter and packing operations, heating, refrigerating, and lighting. Natural gas and (at one plant) propane supplied from 24 to 69 percent of the total energy purchased and electricity the remainder. Gas was used primarily to heat water, generate steam, and smoke and cook products. Typically about 50 percent of the electricity was needed to operate the refrigeration system, 40 percent to power plant equipment, and 10 percent to illuminate the facility.

This report is limited to the electricity used for lights. Many of the different types of lamps suitable for use in meat plants are discussed, and graphic data that can be used to evaluate present lighting are presented. The data can also be used to plan more energy-efficient lighting for other meat industry plants regardless of volume and type of operation.

AVAILABLE LIGHTING SYSTEMS

Only a few jobs at meatpacking plants can be performed using daylight for illumination. The remaining work requires some form of artificial illumination. For years, incandescent lamps were the only light source used by the meat industry. Incandescent lamps provide maximum lumen[2] output as soon as they are switched on, and the quantity of illumination is unaffected by the ambient temperature. Incandescent lamps are available in a wide range of special types and wattages. They continue to provide light whenever voltages fluctuate and are easy to replace when burned out. The quality of the illumination is excellent as the color rendering of meat is similar to that under daylight.

Incandescent lamps have some drawbacks, and these become more important with the increase in energy costs. Only about 10 percent of the electricity used to heat the tungsten wire filament to incandescence is converted into visible light; the remainder is converted into heat. The amount of lumens such lamps produce gradually decreases to about 80 percent of initial light output at the end of their life. Finally, they have a short life (ranging from about 750 to 1,000 hours).

Recently, tungsten-halogen lamps have replaced the regular incandescent lamps for illuminating some areas in many plants. The tungsten-halogen lamp, a type of incandescent lamp, also converts only 10 to 12 percent of the energy consumed into useful light. Tungsten-halogen lamps have some advantages over the older incandescent lamps; they maintain about 95 percent of their initial lumen output throughout the lamp life and generally require smaller luminaires because the bulbs are smaller. They have some disadvantages as well; replacement lamps are much more expensive, some lamps with high initial lumen output have an average life of only about 400 hours, enclosed luminaires are usually required, and if they operate at over 110 percent of rated voltage, the lamps may shatter.

Fluorescent light is produced by passing an electric current through electrodes that generate ultraviolet radiation that in turn is converted into visible light by a fluorescent coating on the inside of the tube. Since the first practical fluorescent lamp was developed over 40 years ago, many improvements have been made to make it a very versatile light source. Fluorescent lamps are available in different lengths, wattages, and special types. Some lamp types render meat colors almost the same as the colors under incandescent lamps, and many plants have them in locations where meats are prepared and inspected.

Fluorescent lamps are superior to incandescent lamps in many ways. They are more efficient (about 22 percent of the energy consumed is converted into visible light, and they produce two or three times as much illumination as incandescent lamps of the same wattage); they have an average life of 9,000 to 12,000 hours; replacement lamps are cheaper (when lamp life is considered); and they generate about one-third

[2]The amount of light output or quantity of illumination is measured in lumens.

the heat of incandescent lamps for the same lumen output. Of course, fluorescent lamps also have some disadvantages. Their lumen output is normally at a maximum at an ambient temperature of 77° F, and the light output of open luminaires can drop significantly at temperatures much lower or higher; special lamps, luminaires, and ballasts are usually needed for low-temperature areas such as product coolers and freezers. The lumen output of fluorescent lamps is spread around and along the length of the lamp, and a significant amount of the light produced may not reach the work area. In cases where carcasses and meats are prepared and inspected and 50 footcandles of light is required, fluorescent lamps might not be the best choice if the distance between the luminaire and the workplace is 5 feet or greater.

Mercury-vapor lamps were introduced about 45 years ago in a 400-watt size and are now produced in 40- to 1,000-watt sizes. They are classified as high-intensity discharge (HID) lamps because their light is produced by passing an electric current through a discharge tube that contains a vapor or gas; the discharge tube is mounted inside a vacuum bulb. In the meat industry these lamps are usually used to illuminate outside areas at night and inside work and storage areas where the luminaires are more than 5 feet above the workplace.

Mercury-vapor lamps are superior to incandescent lamps primarily because they produce about twice as much illumination per watt and have an average life of 24,000 hours. They are also superior to fluorescent lamps in that the lumen output of their luminaires can be focused better, they are available in lamps with higher wattages and more illumination, and their life is twice that of the average fluorescent lamp. They also have some unfavorable features. Mercury-vapor lamps require about 5 minutes to reach maximum lumen output when started and 5 minutes to restart if electrical current flow rate drops or is momentarily interrupted, they consume about twice as much energy per lumen produced as fluorescent lamps, and their initial lumen output gradually decreases (at the end of their life clear glass lamps produce about 70 percent of their original lumen output and coated glass lamps about 60 percent).

The metal halide lamp is a recently developed HID lamp whose use is still limited because it is so new. The lamps are slightly smaller than mercury-vapor lamps of the same wattage, and they produce about twice as much illumination per watt of electricity. The color-rendering abilities of its light are superior to mercury-vapor light. The time required to start and restart the lamps and the depreciation of the lumen output during the lamp life is about the same for metal halide as for mercury-vapor lamps. The metal halide lamp is perhaps the best light source for work areas where inspection requires 50 footcandles of illumination and the distance between the luminaire and the workplace is greater than 5 feet.

The high-pressure sodium lamp, another recently developed HID lamp, is the most energy-efficient lamp available when light output requirements exceed about 33,000 lumens. It comes in a wide range of wattages and is recommended for outside lighting and such interior locations as warehouses and product storage areas. Because high-pressure sodium light has a golden-white appearance, it is not used to illuminate areas where carcasses are inspected, dressed, graded, fabricated into cuts, processed, or packaged. The average lamp life and decline in lumen output are similar to those of mercury-vapor lamps. It takes high-pressure sodium lamps 3 to 4 minutes to reach maximum lumen output and only 1 to 4 minutes to regain it after a short interruption of power.

The low-pressure sodium HID lamp is the most energy-efficient light source available when less than 33,000 lumens per lamp is required. This lamp was developed in Europe in the early 1930's and for a short period prior to World War II was manufactured in the United States, but a combination of unreliability, high cost, and low electricity costs caused its demise. Recently, the low-pressure sodium lamp has started a comeback. Its light has a yellow appearance and should be used to illuminate the same areas that high-pressure sodium lamps are used in. These lamps now have a warranted minimum service life of 18,000 hours or 2 years and their lumen output does not abate during lamp life. The startup and restart time is similar to that of the high-pressure sodium lamp.

Most HID luminaires can be provided with an emergency lamp that switches on automatically when the luminaire is first turned on or when voltage drops or power is momentarily interrupted, causing the HID lamp to extinguish. The emergency lamp usually is a single-ended 250-watt tungsten-halogen lamp that is placed in the same

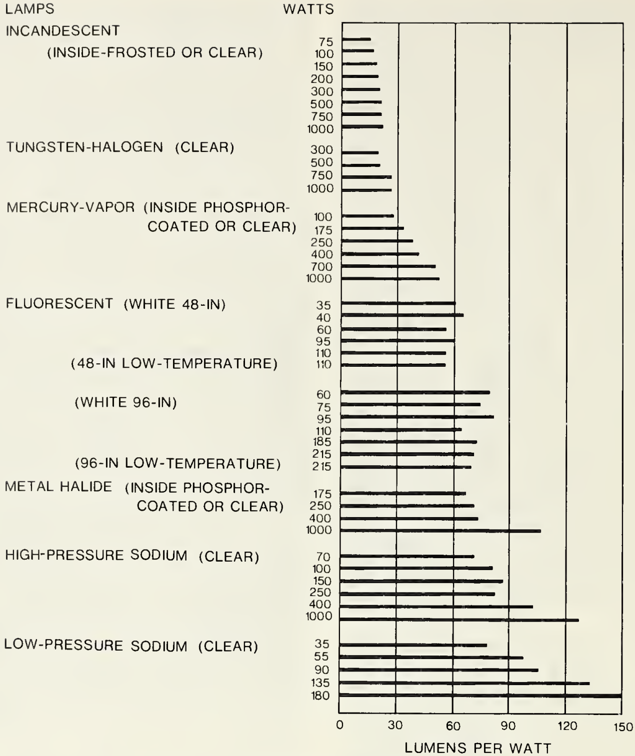

FIGURE 1. — Average initial efficiency of various lamps.

reflector with the HID lamp. When the HID lamp reaches about 50 percent of normal illumination, the emergency lamp is automatically extinguished.

Fluorescent lamps and the four types of HID lamps require a ballast for the luminaire to provide the starting voltage and to limit the electric current. Normally, the ballast is a part of the luminaire, but it can function at a remote location. A ballast consumes energy while operating and continues to do so as long as a luminaire is on, even if the lamp or lamps are missing or burned out. The life of a ballast can be shortened if a lamp is removed or a burned-out lamp remains in a luminaire and the electricity is not switched off. A typical ballast consumes from about 10 to 70 percent of the wattage of the lamp or lamps in a luminaire.

Figure 1 shows the average initial efficiency of various lamps at different wattages. The lamps included are similar to those found in meat plants. Initial efficiency is the ratio of a new lamp's light output in lumens to the electrical energy input in watts. If all the energy put into a lamp were emitted as green light at the wavelength at which the eye is most sensitive, a theoretical maximum efficiency of 680 lumens per watt would be obtained. If the total energy input could be emitted uniformly over the visible spectrum as white light, the efficiency would be on the order of 200 lumens per watt (Weast 1970). To present

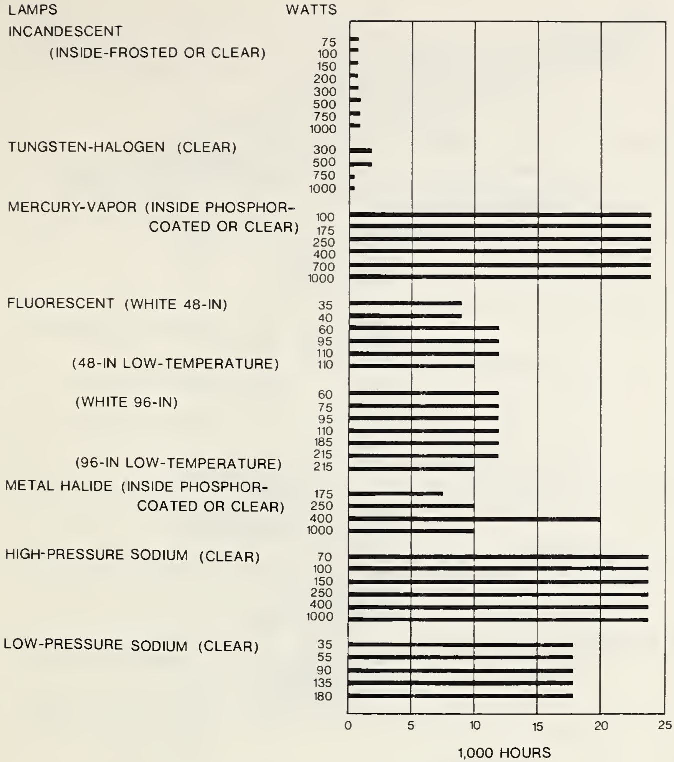

FIGURE 2. — Average life of various lamps.

the lamp's initial efficiency more accurately, the wattage requirements of the ballast were added to the wattage requirements for fluorescent and HID lamps. The four most energy-efficient light sources are the fluorescent, metal halide, and high- and low-pressure sodium lamps.

Lamp life depends to some extent on the average length of the burning cycle. Lights that are on 6 hours or more generally last longer than lights that are switched on and off a number of times each day. High ambient temperatures and fluctuations in voltage can also shorten the life of a lamp, as can luminaires that do not protect the lamps from environmental hazards. The average service life of the lamps discussed, as rated by the manufacturer, are shown in figure 2. Lamp life is based on typical operating conditions and burning cycles of 5 to 10 hours per start. Obviously, when only lamp life is considered, the two types of incandescent lamps are poor choices.

Lamp purchase costs prorated over each hour of life are shown in figure 3. Costs for incandescent lamps of 75 to 300 watts compare favorably with the costs for all fluorescent and most of the HID lamps. Tungsten-halogen lamps are by far the most costly lamps because they cost more initially and their average life is not especially long (750- and 1,000-watt tungsten-halogen lamps have an average life of only 400 hours). There are 750- and 1,000-watt lamps available that have a

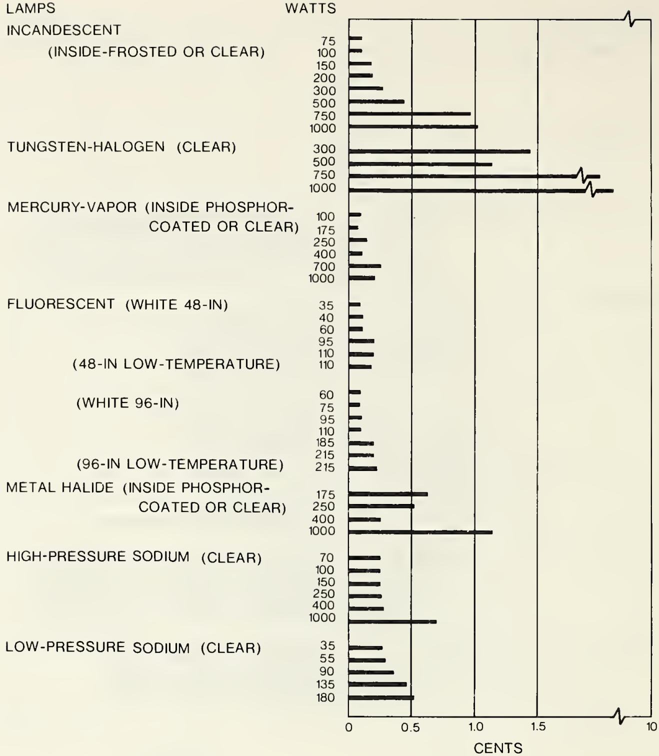

FIGURE 3. — Average lamp cost per hour of life.

2,000-hour life, but only 400-hour lamps were observed in the plants surveyed.

Lamp operating costs are perhaps the most important factor to consider in planning an energy-efficient lighting system. Figure 4 presents the estimated operating costs for 1,000 lumens (from new lamps) in dollars per 1,000 hours of operation. These costs do not include the costs of the luminaires complete with one or two lamps, the wiring and other materials used during installation, or the labor required to install the lighting system. It does include the cost of replacement lamps, labor to replace a burned-out lamp (or two lamps in the case of fluorescent luminaires), and electrical energy consumed. Replacement lamp costs are based on catalog prices for 1979. It is assumed that lamps would be replaced at the time of burnout and that the worker's time would cost a plant $4 per luminaire. An electrical energy cost of 3 cents per kilowatthour (kWh) is used since it is typical of the energy cost at the plants studied.

Labor costs to replace burned-out lamps have a significant effect on determining lamp operating costs. For example, labor costs to replace 300-watt incandescent lamps (which have a life of 750 hours) represent about 31 percent of the total operating costs shown in figure 4. To replace 1,000-

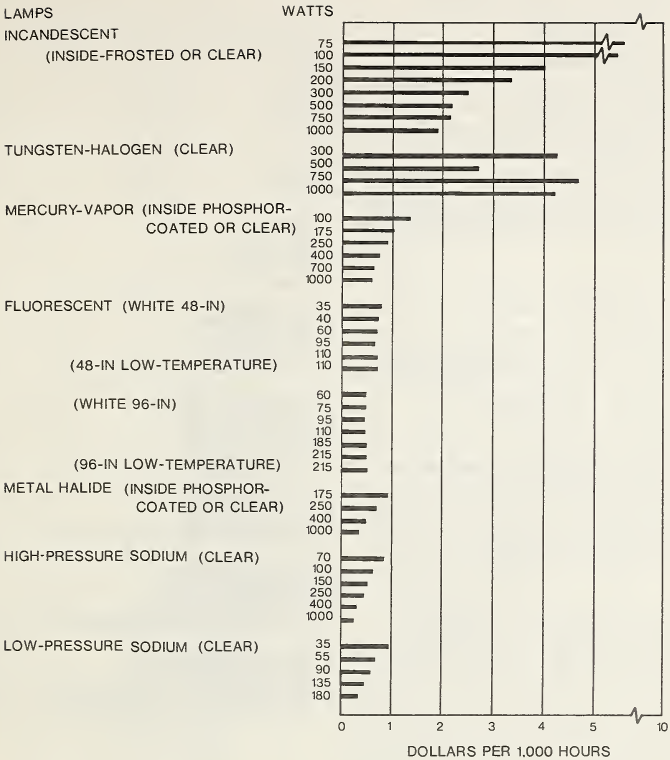

FIGURE 4. — Estimated luminaire operating cost per fixture for its initial 1,000 lumens.

watt high-pressure sodium lamps (which have a life of 24,000 hours) labor costs comprise only about 0.43 percent of the operating costs.

Because each watt of electrical energy used for illumination also represents 3.413 British thermal units (Btu) of heat, the type of lighting system provided can affect the total heat load in artificially cooled rooms. Fluorescent and HID lamps provide more lumens per watt than incandescent lamps and thus produce fewer Btu's per lumen. Figure 5 shows the average lumen output per Btu produced by the different lamps.

By correlating the information on figures 1-5, plant operators should be able to evaluate their present lighting systems and to plan changes to provide more energy-efficient lighting. Also, before any luminaires are purchased, a qualified lighting engineer or luminaire distributor should be contacted for assistance in selecting the best lighting systems for the different work and storage areas. Top-quality fluorescent and HID luminaires are much more expensive than most incandescent luminaires, but they should last a number of years and require very little maintenance other than periodic cleaning. In most cases the savings in electrical energy and demand charges should pay for fluorescent or HID luminaires and their installation within a few years.

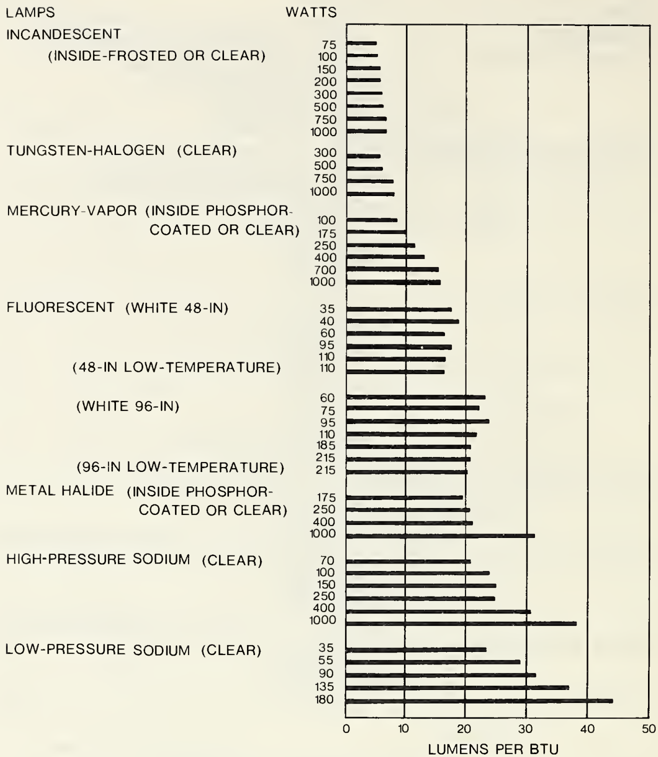

FIGURE 5. — Average lumen output per Btu produced by various lamps.

Table 1. — Efficiency of present and suggested lighting systems in six slaughter plants

Plant	Present lighting system			Suggested lighting system		
	Energy used (watts)	Illumination provided (lumens)	Average efficiency (lumens/watt)	Energy used (watts)	Illumination provided (lumens)	Average efficiency (lumens/watt
1	25,522	992,550	38.9	15,126	1,054,750	69.7
2	25,226	750,810	29.8	12,241	821,550	67.1
3	28,036	1,320,250	47.1	20,037	1,353,200	67.5
4	34,442	1,434,300	41.6	21,388	1,509,000	70.6
5	52,865	2,555,750	48.3	36,684	2,641,150	72.0
6	68,012	2,258,550	33.2	35,113	2,293,400	65.3

LIGHTING SYSTEMS AT SURVEYED PLANTS

At each of the six plants studied, the location and type of light source, number and wattage of lamps, and the arrangement of luminaires were recorded. Using the information provided in the preceding section plus data obtained from lamp manufacturers, total lamp wattage and initial lumen output were computed for each of the work and storage areas at the plants. Suggested lighting systems were then developed using more energy-efficient lamps.

The type of activity conducted in each area during the selection of more energy-efficient lighting was considered. For example, when sodium lamps are suggested to replace incandescent lamps in a livestock pen area, one or more fluorescent luminaires should also be included to provide good color rendering for antemortem inspection of live animals. Low-wattage incandescent lamps that are normally switched on and off a number of times daily and whose total time in operation averages only a few hours need not be replaced because the cost of more energy-efficient luminaires is not justified. In all cases the total initial lumen output of the lamps suggested exceeds the present lamps.

A comparison of the present lighting systems at the six plants with the systems suggested is shown in table 1. The most energy-efficient lighting system was found at plant 5 (average efficiency, 48.3 lumens per watt). While most of the proposed energy reduction shown in table 1 can be attributed to more efficient lamps, some minor reductions are included that can be achieved by adopting such energy conservation procedures as installing photoelectric controls on outside security lights to turn the lights on at dark and off at dawn, connecting timers to light switches in low-use area to automatically cut off the lights after a short period, installing additional light switches in large areas so that lights can be turned on only where the workers need illumination, and requiring the crew leaders to see that all unnecessary lights are switched off during such times of low activity as the lunch period and near the end of the day.

The estimated kilowatthours of electricity used monthly by each type of lighting at the six plants is shown in table 2. It is apparent from this information that plant 2's comparatively poor

Table 2. — Estimated amount of electricity used monthly by each type of lighting in six slaughter plants

Plant	Total lighting[1] (kWh)	Incandescent: Regular kWh	Incandescent: Regular % of total	Incandescent: Tungsten-halogen kWh	Incandescent: Tungsten-halogen % of total	Fluorescent kWh	Fluorescent % of total	Mercury-vapor kWh	Mercury-vapor % of total	High-pressure sodium[2] kWh	High-pressure sodium[2] % of total
1	6,808	1,839	27.0	1,873	27.5	3,096	45.5	....	....	....	....
2	5,573	4,199	75.4	....	....	732	13.1	642	11.5	....	....
3	6,645	3,134	47.1	....	....	3,262	49.1	249	3.8	....	....
4	7,164	2,288	31.9	1,872	26.1	3,004	42.0	....	....	....	....
5	17,522	3,423	19.5	1,483	8.5	9,563	54.6	3,053	17.4	....	....
6	14,295	7,665	53.6	1,995	14.0	3,160	22.1	416	2.9	1,059	7.4

[1]Based on outside security lights in use about 12 hours nightly, holding-pen lights in use about 5 hours each workday, and plant lights in use about 10 hours each workday (except at plant 5 where some plant lights were on about 19 hours each workday).

[2]High-pressure sodium lights were used for outside security.

Table 3. — Estimated amount of electricity needed monthly by each type of lighting after adopting energy-conservation procedures and installing energy-efficient lights in six slaughter plants

Plant	Total lighting[1] (kWh)	Incandescent		Fluorescent		Mercury-vapor		High- or low-pressure sodium[2]		Metal halide[3]	
		kWh	% of total	kWh	% of total	kWh	% of total	kWh	% of total	kWh	% of total
1	3,364	159	4.7	1,323	39.3	...	...	436	13.0	1,446	43.0
2	2,671	21	.8	1,710	64.0	187	7.0	233	8.7	520	19.5
3	4,370	...	...	3,561	81.5	249	5.7	292	6.7	268	6.1
4	4,448	...	...	3,868	87.0	...	...	...	...	580	13.0
5	13,045	204	1.6	9,726	74.5	...	...	855	6.6	2,260	17.3
6	7,595	504	6.6	3,111	41.0	...	...	1,059	13.9	2,921	38.5

[1]Based on outside security lights in use about 12 hours nightly, holding-pen lights in use about 5 hours each workday, and plant lights on several hours in low-use areas and about 10 hours in high-use areas each workday (except at plant 5 where plant lights are on about 19 hours each workday in high-use areas).

[2]High- or low-pressure sodium lights to be used for outside security, livestock-holding areas that are not used for antemortem inspection, storage rooms, and other areas where products are not prepared and inspected.

[3]Metal halide lights to be used for plant lighting where livestock are slaughtered and where products are prepared and are subject to visual inspection.

Table 4. — Estimated hourly reduction in lighting heat load in refrigerated rooms by installing energy-efficient lamps, six slaughter plants

[Btu's per hour]

Plant	Room temperature (°F)			Total
	50	32	−10	
1	3,994	5,829	....	9,823
2	....	19,931	3,038	22,969
3	4,143	1,475	2,417	8,035
4	....	7,885	....	7,885
5	....	9,608	6,870	16,478
6	4,478	69,456	....	73,934

Table 5. — Estimated monthly savings in electrical energy caused by reduction in lighting heat load in refrigerated rooms, six slaughter plants

[Kilowatthours]

Plant	Room temperature (°F)			Total
	[1]50	[2]32	[3]−10	
1	126	201	...	327
2	...	625	185	810
3	123	48	151	322
4	...	249	...	249
5	...	571	757	1,328
6	130	2,210	...	2,340

[1]Based on an energy-efficiency rating of 7.2 Btu/h/W for the refrigeration system.

[2]Based on an energy-efficiency rating of 6.6 Btu/h/W for the refrigeration system.

[3]Based on an energy-efficiency rating of 3.4 Btu/h/W for the refrigeration system.

efficiency (29.8 lumens per watt) was caused by the fact that over 75 percent of its total illumination was supplied by incandescent lamps.

By installing more energy-efficient lamps and adopting conservation procedures, the plants should reduce significantly the amount of energy needed for illumination (table 3). All tungsten-halogen lamps should be replaced with more efficient fluorescent, sodium, or metal halide lamps. The remaining incandescent lamps should be located in low-use areas such as restrooms with windows, hide-curing rooms, and equipment rooms. The mercury-vapor lamps located inside the facility at plants 5 and 6 should be replaced by sodium and metal halide lamps. At plants 2 and 3, mercury-vapor lamps for outside security at night need not be replaced because the savings

Table 6. — Estimated annual savings in electrical energy consumption, demand, and lamp replacements by installing energy-efficient lamps in six slaughter plants

Plant	Electrical energy savings				Demand savings[1]		Lamp replacement savings[3] (dollars)	Total savings (dollars)
	Lighting (kWh)	Refrigeration (kWh)	Total (kWh)	Savings[2] (dollars)	Lighting (kWh)	Savings[2] (dollars)		
1	41,328	3,924	45,252	1,326.79	108	540.00	785.88	2,652.67
2	34,824	9,720	44,544	1,112.71	144	552.96	1,570.39	3,236.06
3	27,300	3,864	31,164	954.86	72	102.24	787.45	1,844.55
4	32,592	2,988	35,580	952.12	120	220.80	966.20	2,139.12
5	53,724	15,936	69,660	1,973.47	144	342.72	735.30	3,051.49
6	80,400	28,080	108,480	2,829.16	360	662.40	3,013.17	6,504.73

[1]Savings limited to the probable maximum kilowatt-load reduction resulting from use of more energy-efficient lights.
[2]Savings based on utility schedules in effect at the time of the study at each plant.
[3]Savings based on the cost of the replacement lamps plus labor (at $4 per luminaire).

in energy costs would probably not be enough (for the time being) to warrant converting to sodium lamps.

Another savings for these plants is a reduction in the lighting heat load in refrigerated rooms brought about by the installation of energy-efficient lights (table 4). Heat-load savings at plants 1, 3, and 4 are not very significant for any single room because a number of rooms and refrigeration compressors are involved, but at plant 6 about 49,500 Btu per hour could be eliminated in one 32° F cooler by installing metal halide lights.

Were each plant to profit fully from the reduction in the lighting heat load in refrigerated rooms, then the refrigeration units should operate for shorter periods and would consequently use less electricity. Table 5 shows the estimated monthly savings caused by the reduction in the lighting heat load. The energy-efficiency ratings for the refrigeration systems at the three different room temperatures are based on air-cooled compressor units and fluorocarbon refrigerants (Stahlman 1972).

Two additional benefits should accrue to the six plants if they were to install the suggested lighting systems and adopt energy conservation procedures. The first benefit would be a reduction in the maximum kilowatt load (demand) and the second would be reduced labor requirements since there would be fewer burned-out lamps to replace annually. Table 6 shows the estimated annual savings in electrical energy and demand and in replacement lamps and labor after the installation of more energy-efficient lighting systems. To estimate the reduction in electrical demand, all lamps used at night for security and for illuminating the livestock pens were subtracted from the wattages shown in table 1. At all 6 plants, the utilities based demand on the kilowatt load established during the 15-minute period of maximum energy use during the month. When the annual estimated energy and demand savings are compared with the total actual billing charges, the reduction in annual electrical costs ranges from about 3 to 8 percent and averages about 5 percent.

Table 7. — Estimated reduction in total energy purchased, electrical energy purchased, and average monthly demand by installing energy-efficient lamps in six slaughter plants

Plant	Energy purchased		Electrical demand (%)
	Total (%)	Electricity (%)	
1	2.4	5.1	5.3
2	3.5	4.6	6.8
3	.8	2.6	2.3
4	1.7	3.3	4.4
5	2.0	4.1	4.2
6	3.0	7.2	8.8

The estimated percentage of reduction in total energy purchased, electrical energy purchased, and average monthly electrical demand is shown in table 7. The comparatively low reduction in total energy purchased (0.8 percent) at plant 3 is a result of a lighting-energy reduction of only about 28.5 percent (table 1) from installation of the suggested lighting system. However, at plant 2, installing the suggested lighting system should reduce the total energy purchased by a far more significant amount (3.5 percent) because the installation of energy-efficient lamps and adoption

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of conservation procedures should save about 51.5 percent of the present lighting energy required. (table 1).

SUMMARY AND RECOMMENDATIONS

Both regular and tungsten-halogen incandescent lamps that are located in high-use areas should be replaced by fluorescent or HID lamps. The operating costs per 1,000 lumens is $3.36 per 1,000 hours for a 200-watt regular incandescent lamp and only 79 cents for a 2-lamp 82-total-wattage fluorescent luminaire. In addition, the initial output of the incandescent lamp is about 3,900 lumens while that of the 2-lamp fluorescent luminaire is about 5,000 lumens. For both refrigerated and unrefrigerated work and storage areas where carcasses are dressed, graded, fabricated into cuts, prepared into various products, and inspected, the most energy-efficient and lowest cost lighting presently available are fluorescent and metal halide lamps. In most cases, fluorescent lamps are the best choice when the luminaires are located within about 5 feet of the workplace and metal halide lamps when luminaires are more than 5 feet above.

For outside security lighting and to illuminate areas where live animals are unloaded and held prior to slaughter, high- or low-pressure sodium lamps are suggested. Also where packaged meats, other products, and supplies are handled and stored and no inspection is required, sodium lamps are recommended since they have the lowest operating costs and provide both the most lumens per watt and lumens per Btu of energy output.

The average efficiency of the lighting systems found at the six plants studied ranged from about 29.8 to 48.3 lumens per watt. If the suggested changes are made, these plants should increase the average efficiency from about 65.3 to 72.0 lumens per watt. By replacing the present lighting system with the suggested system and adopting conservation procedures, these plants should reduce the amount of electrical energy needed for illumination and refrigeration, electrical demand, and labor requirements to replace burned-out lamps.

When the total amount of natural gas, propane, and electrical energy presently consumed (in Btu's) is compared with the amount of electrical energy saved by the suggested installation of more energy-efficient lights and the adoption of conservation procedures, the total energy savings ranged from about 0.8 to 3.5 percent. The savings in electrical energy alone ranged from about 2.6 to 7.2 percent. Electrical demand savings ranged from about 2.3 to 8.8 percent.

As a rule of thumb, when the average efficiency of lighting is more than 40 lumens per watt for an area, then perhaps only the luminaires with the lowest lumen per watt value should be replaced. Whenever the area average is less than 40 lumens per watt, probably most or all of the luminaires should be replaced.

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